Working papers series

WP ECON 15.10

Labor Demand and ICT Adoption in Spain

Manuel Hidalgo-Pérez (U. Pablo de Olavide)

Jesús Rodríguez-López (U. Pablo de Olavide)

José M. Okean (U. Pablo de Olavide)

Keywords: Productivity, TFP, ICT, education

JEL Classification: I24, J24, O40

Department of Economics

Labor Demand and ICT Adoption in Spain

Manuel Alejandro Hidalgo-Pérez
Universidad Pablo de Olavide
Carretera de Utrera km. 1
41013, Sevilla (Spain)
email: mhidper@upo.es

José María O'Kean-Alonso
Universidad Pablo de Olavide
Carretera de Utrera km. 1
41013, Sevilla (Spain)
email: jmokean@upo.es

Jesús Rodríguez-López (corresponding autor)
Universidad Pablo de Olavide
Carretera de Utrera km. 1
41013, Sevilla (Spain)
email: jrodlop@upo.es

July 6th 2015

Abstract: Spain is delayed in adopting information and communication technologies (ICT) and its productivity per hour worked presents a downward trend since the mid 90s. In this paper we argue that these two facts are related. Using the EU KLEMS dataset we test the capital-skill complementarity hypothesis in a cross-section of sectors in Spain. We find that the substitutability between workers and ICT assets falls as worker skill level rises, and that this feature holds across all sectors. Furthermore, the ICT assets are complementary with skilled workers. The fraction of workers employed with medium and high skills across sectors rose by 21% and 12%, respectively, to the disadvantage of low skilled workers, due to an adjustment within sectors more than to a composition effect between sectors. Finally, using a regression analysis, we conclude that some labor market institutions are likely behind the evolution of sectorial productivity and ICT investment in Spain.

JEL Classification: I24, J24, O40

Keywords: Productivity, TFP, ICT, education.

Acknowledgements: The authors would like to thank E. Alonso, M: Camacho, J.C. Conesa, G. Fernández de Córdoba, M. Mas, and J. L. Torres for their helpful comments and suggestions. We acknowledge financial support from Proyecto Excelencia Junta de Andalucía P14-SEJ-1512.

Labor Demand and ICT Adoption in Spain

Manuel A. Hidalgo Pérez
Universidad Pablo de Olavide

José María O'Kean Alonso
Universidad Pablo de Olavide

Jesús Rodríguez López (corresponding author**)**
Universidad Pablo de Olavide
Carretera de Utrera km. 1
41013, Sevilla (Spain)
email: jrodlop@upo.es

July 6, 2015

1 Introduction

Information and communication technologies (ICT), which have spread more rapidly and bolstered productivity more effectively than earlier technologies, have had a definite impact on the economy. Numerous studies have pointed to the special role played by these assets in the recovery of productivity growth since the mid-1990s in the United States and some European countries. Such a change implies an active adaptation process, as worker skills are changed to suit the new technologies and firms reorganize, replacing unskilled workers with others whose training and experience are appropriate to the new context.

ICT-driven changes have intensified the need for a skilled workforce, increasing both the demand for and the productivity of qualified workers and causing a rise in the relative wage of this group, especially in ICT-intensive countries such as the U.S., the U.K. and Sweden (Autor, 2002; Acemoglu, 2003). The fact that the price and the cost of ICT assets have fallen steadily worldwide during the past two decades –more intensely if we take quality adjusted prices into account— suggests a complementary relationship between these assets and highly skilled workers. On the other hand, the weight of low-skilled workers, who tend to concentrate in sectors where computers and information systems are used less intensively, such as construction or seasonal activities, has diminished.

In Spain, the composition of labor demand has changed as the use of ICT has risen across sectors. Mas and Quesada (2006) have shown that human capital employment has been stronger, the higher the intensity ICT assets have been used in a sector. Spain has used ICT assets less intensively than other OECD economies. In this sense, Spain is a good case study to help understand the capital-skill complementarity hypothesis, as there are sharp contrasts between sectors. Our aim is to estimate for Spain the elasticities of substitution between inputs, including workers of different skill levels and different assets (ICT and non-ICT). Using the EU KLEMS database, we can perform this estimation for a decomposition of 24 productive sectors between 1980 and 2005, comprising industrial activities and market services. This period has witnessed the main process of growth in recent Spanish history: the transition to democracy after a long dictatorship with a tightly intervened economy, the openness following Spain's EEC entry, and some crucial reforms which allowed the fulfilment of the Maastricht criteria and the early adoption of the Euro in 1999. Due to the limitation of EU KLEMS data, the period under consideration, notwithstanding, excludes the great recession starting in 2008 and still ongoing.

We reach the following findings. First, we show that changes in hours worked were motivated by adjustments within sectors, rather than adjustments between sectors: the percentage of workers employed with medium and high skill rose by 21% and 12%, respectively, while the employment of low skilled workers fell by 33%. Second, the degree of substitutability between capital and labor is lower the higher the skill of workers is. Specifically, for low skilled workers, the elasticity of substitution was 2.07 with respect to communications equipment, 4.07 with respect to computer hardware, and 5.98 with respect to computer and software licenses. For the medium-skill workers, the results indicate complementarity with communication equipment (-2.17), but substitute with hardware and software in a similar magnitude to that of low skilled workers. And for the high-skill workers, we find them complementary with all ICT assets. On the other hand, the elasticity of substitution of non-ICT capital assets with all workers, regardless of skill level, was 2.00. Finally, we find the ICT assets are complementary between them, and substitutive with the non-ICT assets.

To our knowledge, this is the first paper that tests the capital-skill complementarity hypothesis for sectors in Spain, controlling for workers education and capital assets embedding different technological progress. Our findings do not differ much from those estimated for other countries: skills complement technology. Yet, the Spanish case serves as an experiment to test whether this hypothesis depends on the ICT intensity: we take the few sectors that use ICT intensely as a treatment group and the low intensive users as a control group, and conclude that the capital-skill complementarity still holds. Hence, we endeavour in identifying those restrictions that reduce firms' incentives to adopt new technologies. Several labor market and goods market institutions are natural candidates to help explain the existence of barriers to technology adoption (Gust and Márquez, 2004).

A second (complementary) explanation deals with the transformation of the sectorial composition occurred after Spain became an EEC member in 1986, and the liberalization followed by the Single European Act in 1987. Trade policies can have important effects on efficiency, measured as total factor productivity (TFP), and can change incentives for both domestic savings and foreign investment. The Spanish economy specialized in non tradable activities, such as construction, real estate services or tourism, barely exposed to international trade competition. Trade and foreign investment liberalization changed Spanish firms' incentives to incorporate technology and, thereby, reap the gains in productivity (Delgado, Fariñas and Ruano, 2002). Growth accounting exercises (Mas and Quesada, 2006) find that the Spanish economy shows notable inefficiencies, with negative TFP growth during the period 1985-2004. The ICT intensive sectors, however, reversed such a trend since 2000, with an upsurge in labour productivity, albeit most of these intensive sectors are non tradable activities.

In Section 5, using a regression analysis, we consider whether institutional transformations and higher openness can provide a ground for the particular evolution of TFP and ICT investment across sectors in Spain. We find significant correlation of both variables with some labor market institutions: employment protection, the particular dual structure of the Spanish labor market, and the degree of centralization of collective bargaining. Some other indicators concerning the facility to trade in international markets are found correlated with ICT investment, but not with TFP growth. The temporary rate (i.e. the ratio of the number of wage earners under a fixed-term contract relative to the total number of workers) increased 23 percentage points during the period we study. While these fixed-term contracts tend to be associated with low skilled workers, according to the regression results, the 23% increase produced a TFP deceleration of 1.84% and accounts for a reduction in the ICT investment share of 5.87%.

This article is structured as follows. In Section 2 we study the relationship between ICT and human capital in Spain. Using simple techniques, we decompose the changes in the fraction of workers employed for each category in two sources: intersectional and intrasectional changes. In Section 3, we propose a translog costs function to estimate the functions of input demand and different elasticities. We describe the evolution of relative input prices. The econometric results of this estimation are presented in Section 4. In Section 5 we use a regression analysis to explore which institutional elements are likely behind sectorial TFP and ICT investment in Spain. Section 6 finally concludes.

2 ICT, productivity and education

Several studies which include those by Jorgenson (2001) Colecchia and Schreyer (2002), Stiroh (2002), and Timmer, Ypma and van Ark (2003) have confirmed the following: First, ICT assets accumulation in the European Union economies and the U.S. over the past thirty years has risen more sharply than that of non-ICT asset; Second, productivity growth has increased in parallel with the rise in ICT use; And third, ICT accounts for a considerable fraction of growth in countries where the use of this technology is more intensive.

The technological progress embodied in these assets can help explain this relationship between productivity growth and the intensity of ICT use (Rodríguez-López and Torres, 2012). For instance, a computer is a means of technology adoption, which translates into higher productivity. On the other hand, technological progress that incorporates traditional non-ICT assets is rather limited relative to ICT ones (Cummins and Violante, 2002).

The adoption of new technologies is not cost-free, and often requires firms to implement organizational changes and new ways of doing business. Because this process of technological adaptation involves a high volume of resources, the advantages associated with ICT use are not immediately evident. One effect of ICT use has been to get rid of these routine tasks, and to free up large blocks of time which could then be filled with other tasks. As ICT use intensified during the 1990s, aggregate growth and labor productivity rates began to rise above the levels that they had displayed during the 1970s.

In order to illustrate differences across countries, for a set of countries for which we have comparable data in the EU KLEMS data base (update March 2011), Table 1 reports the growth rate of TFP and the weight of ICT investment in the portfolio of capital assets (including residential capital), for three quinquennial averages. Unfortunately, complete data for Belgium, France, Ireland and Portugal are not available. Average TFP growth was rather low during the 90s. In the mid 90s, with the exception of Sweden, all countries belonging to the EU present a break, downsizing the growth rate of TFP of these countries. In Denmark, Italy and Spain, TFP exhibits a downward trend. While Sweden, the UK and the US devoted about 20% of total gross fixed investment to the ICT since the mid nineties, Italy or Spain did around 9%. As for the Spanish case, in the regression analysis of Section 5, we will show that certain institutional disruptions related to the labor market can account for these two gaps.

An integral part of this process has been the substitution of many existing workers, who had never used ICT on the job and were unskilled to do so, by new and better-trained ones more familiar with the new equipment. The latter have reaped the greatest benefits from the technological revolution, which spurred a rise in their wages. Changes of this type have been observed for periods marked by other kinds of technological change. For example, Goldin and Katz (1998) have shown how the electrical revolution significantly altered the shape of US labor demand during the early twentieth century. Another example is Berman, Bound and Griliches (1994).

Regarding Spain, it is worth mentioning the particular evolution of its productivity per hour worked. At the sectorial level, this issue is analyzed by Mas and Quesada (2006), who conclude that the decline in productivity was a common feature for most of the sectors in Spain. Because ICT use is relatively smaller as compared with that of the US and other European countries (Table 1), non-ICT capital has a greater impact on Spanish productivity growth.

Mas and Quesada (2006) characterize as ICT-intensive sectors those activities for which this proportion exceeded the average in 2004. According to this criterion, eight sectors can be classified as intensive users of ICT: (1) Pulp, paper, printing and publishing, (2) Electric, electronic, optical equipment, (3) Energy and water, (4) Transport and communication services, (5) Financial and banking services, (6) Business services, (7) Private health and social services, and (8) Other community services. These intensive users of ICT only account for a third of total Gross Value Added (GVA) in Spain, and with the exception of the two first sectors, most of them are service activities or Energy and Water, usually considered as non tradable sectors.

Figure 1 reports productivity per hour worked for the aggregate economy and for the two groups of sectors (all first observations have been normalized to one). In Spain, productivity per hour worked increased until the mid 80s. After that date, the growth rate of productivity steadied and presented a downward trend in the mid 90s. This downturn has been documented by several authors: Rodríguez-López and Solís-García (2014) find evidence of three structural breaks in productivity in 1985, 1994, and 2006; Jimeno, Moral, and Saiz (2007) argue that the break in productivity occurred as early as in 1992. However, things are different when we control for the intensity of ICT use. While the 1995 break is evident for the non intensive sectors, productivity presents an upward trend over the whole period for those eight sectors using ICT more intensely.

Table 2 extends this idea over the human capital employed according to this classification of sectors. The columns in Table 2 list data on the percentage of hours worked for three skill-level groups in each productive sector during the three pivotal years of our sample –1985, 1995 and 2005— drawn from the EU KLEMS database. The EU KLEMS classification of the skill levels is: high skill refers to those workers with college degrees (university graduate) or above; medium skill refers to workers with secondary education; and low skilled refers to lower secondary education and below (i.e. at most primary education or illiterate). These data show the evolution of the quality of the labor in each sector. In 1985, the percentage of low skill workers was very high in all sectors, especially in those classified as ICT non-intensive. The proportion of highly skilled workers grew continually in all sectors, mostly in the ICT-intensive ones. This ratio practically doubled between 1985 and 2000, averaging 17.7% in 1985, 24.6% in 1995 and 33.6% in 2005. The most important changes can be seen in the drastic reduction in the proportion of low skill workers employed, which dropped from 84.7% in 1985, to 54.5% in 2005.

The ratios shown in Table 2 are also affected by sectorial changes. We use the decomposition technique proposed by Berman, Bound and Griliches (1994) for the US to identify how much of the variation of each type of worker was caused by a sectorial change or by an increased demand for them. An analogous technique is used in Timmer and de Vries (2009) to decompose GDP per worker in a variety of developing countries. Consider three skill levels: high, medium and low, indexed by $j \in \{h, m, \ell\}$, respectively, let $\mathrm{hours}\,(s, j)$ denote hours worked in sector s by workers of skill level j, and let $\mathrm{sh}\,(j)$ denote the proportion of hours worked by those of skill level j (time subscripts have been removed for simplicity). This proportion can be obtained as the weighted average of the participation of these workers in each of our sectors, that is

$$\mathrm{sh}(j) = \sum_{s=1}^{S} \mathrm{sh}\,(s, j)\,\mathrm{sh}\,(s)\,, \tag{1}$$

for sectors $s = 1, \ldots, S$, where, $\mathrm{sh}\,(s)$ denotes the share of hours worked in sector s, and $\mathrm{sh}\,(s, j)$ denotes the fraction of hours worked of workers of skill level j in sector s:

$$\begin{aligned} \mathrm{sh}\,(s) &= \frac{\sum_{j\in\{h,m,\ell\}} \mathrm{hours}\,(s, j)}{\sum_{s=1}^{S} \sum_{j\in\{h,m,\ell\}} \mathrm{hours}\,(s, j)}, \\ \mathrm{sh}\,(s, j) &= \frac{\mathrm{hours}\,(s, j)}{\sum_{i\in\{h,m,\ell\}} \mathrm{hours}\,(s, i)}. \end{aligned}$$

Note: $\sum_{s=1}^{S} \mathrm{sh}\,(s) = 1$, and $\sum_{j} \mathrm{sh}\,(j) = 1$.

From expression (1), the annual rise in the share $\Delta\,\mathrm{sh}\,(j)$ can be decomposed as follows

$$\Delta\,\mathrm{sh}\,(j) = \underbrace{\sum_{s=1}^{S} \overline{\mathrm{sh}}\,(s,j)\,\Delta\,\mathrm{sh}\,(s)}_{Between-group\ \ effect} + \underbrace{\sum_{s=1}^{S} \Delta\,\mathrm{sh}\,(s,j)\,\overline{\mathrm{sh}}\,(s)}_{Within-group\ \ effect}, \qquad (2)$$

where the upper bar denotes a two year average.

1. The first term is the *composition effect* or *between-group effect*, accounting for the variation in the proportion of workers of skill level j due to changes in sectorial composition.
2. The second term is the *within-group effect*, accounting for the changes in the demand for workers of skill level j within a given sector.

Table 3 shows this decomposition for high and medium skills. By default, the results for low-skill workers can be derived from these two categories, making it redundant to list them here. The decomposition is given for the entire period and for five year sub-periods.

For the 1980-2005 period, the percentage of high skill workers employed in Spain rose by 12.16 percentage points. Of these, 8.68 points resulted from changes in intrasectorial demand while the remaining 3.48 points resulted from changes in sectorial composition. Thus, 71.4% of the change during this two-year period was caused by intra-group changes (=8.68/12.16). The growth in the participation rate was very homogeneous throughout the period under study, averaging approximately 2.5%. With the exception of the first five-year period, 1980-1985, the intra-group effect surpassed the inter-group effect. This result can be viewed as a consequence of the industrial reforms that took place in Spain between 1980 and 1985 (a process known as reconversión industrial). From 1996 to the present, nearly all of the change in this rate can be accounted for by intra-group forces.

Also in Table 3, for workers in the medium-skill group the total variation (21.06%) exceeds that observed for highly skilled workers (12.16%). This implies that the greatest adjustment in the composition of hours worked in Spain resulted from the greater employment of medium-skill workers. The percentage of variation in low-skill workers was -33.2%, which implies that those who replaced them were largely with medium skill level. The changes in this proportion – – almost exclusively responded to changes within each sector. In fact, sectorial adjustments contributed negatively to their variation, probably in favour of highly skilled workers. That is, while 22.6% of the overall change can be associated with direct substitutions of low skilled workers by medium-skill ones within each sector, the changes in sectorial composition also gave rise to a weak substitution rate of 1.6% of medium-skill workers by highly skilled ones.

In summary, the results mentioned above point out that most of the transformations observed should be associated with changes within the sectors. Such a pattern of structural change has been also documented by Timmer and de Vries (2009) for a variety of countries, where market services and industrial sectors account for an important bulk of productivity change. The role of the sectorial composition has declined, although it was relevant until the mid 90s. Such changes can have had multiple causes, as dictated by the substitutive and complementary relationships between different factors. In order to know how and why substitutions between workers of different skill levels occurred, we explore the dynamic behind the decision to invest in these technologies.

[**Figure 1 and Tables 1, 2 and 3 here**]

3 The demand for labor and capital

In this section, a trans-log cost function and Shepard's lemma are used to estimate three relevant elasticities: elasticities of demand (own-price elasticities), cross elasticities, and elasticities of substitution. Examples of this same approach can be found in Berman, Bound and Griliches (1993), Machin and Van Reenen (1998), or more recently in O'Mahoney, Robinson and Vecchi (2008), in a similar exercise for some European countries and the US.

For each sector, we consider an arbitrary production function that combines a variety of inputs: hours worked with different skills, indexed as $\{h, m, \ell\}$, ICT assets (hardware, communications and software), indexed as $\{hard, com, soft\}$, and a non-ICT asset, indexed as $non\text{-}ict$. Non-ICT capital is an aggregate of other assets: non-residential structures, transport equipment, machines and mechanical equipment. For this aggregation, in order to account for variations in the relative prices, we use a Törnqvist index.

We combine the data bases of EU KLEMS and Ivie-FBBVA, specific to Spain. From the EU KLEMS database, we use data on hours worked, investment in different assets, labor compensation, capital compensation, gross value added, and gross output. This database contains data series from 1980 to 2007 for 29 productive sectors, and we limit our analysis to 24 sectors.[1] Capital

[1]For a description of this methodology, see Timmer, O'Mahony and van Ark (2007) The data base site is `http://www.euklems.net/`

stock and investment series are also drawn from the database of Ivie-FBBVA, which divides the data into eighteen physical capital assets for 1964-2005.[2]

3.1 Methodology

Let p_s denote the price vector of the seven productive factors under consideration (time subscripts are removed to simplify our notation):

$$p_s = \left[W_{h,s}, W_{m,s}, W_{\ell,s}, R_{hard,s}, R_{com,s}, R_{soft,s}, R_{non\text{-}ict,s}\right]', \tag{3}$$

where W_{is} denotes the hourly wage of workers i in sector s, for $i \in \{h, m, \ell\}$, and R_{jt} denotes the user cost of capital, measured as the rental price of j, for $j \in \{hard, com, soft, non\text{-}ict\}$. In what follows, for simplicity, p_{is} will denote the i-th element of vector p_s in (3).

The cost function of sector s, C_s, is approximated by a second-order translog function:

$$\begin{aligned} \ln C_s = \ln(p_s)'\phi + \frac{1}{2}\ln(p_s)'\mathbf{B}\ln(p_s) + \\ +\frac{1}{2}\lambda_{yy}\ln(y_s)^2 + \sum_i \lambda_{iy}\ln(p_{is})\ln(y_s) + \\ +\eta_{st}t + \frac{1}{2}\eta_{stt}t^2 + \eta_{Yt}\ln(y_s)t + \sum_i \eta_{is}\ln(p_{is})t, \end{aligned} \tag{4}$$

where ϕ is a vector of parameters common to all productive sectors,

$$\phi \equiv \left[\phi_h, \phi_m, \phi_\ell, \phi_{hard}, \phi_{com}, \phi_{soft}, \phi_k\right]'.$$

Variables y_s and t represent the level of output in sector s and time, respectively.

$\mathbf{B}$ is a symmetric matrix, so that

$$\beta_{ij} = \mathbf{B}(i,j) = \mathbf{B}(j,i) = \beta_{ji}, \tag{5}$$

with $i, j \in \{h, m, \ell, hard, com, soft, k\}$.

According to Shephard's lemma, the demand for factor j in sector s, can be obtained through the partial derivative of the cost function with respect to the price of that factor, $C_{js} = \partial C_s / \partial p_{js}$.

[2] http://www.fbbva.es/

Multiplying this derivative by (p_{js}/C_s), the cost share of factor j can be written as

$$\mathrm{sc}\,(j,s) = p_{js}\frac{C_{js}}{C_s} = \frac{\partial \ln C_s}{\partial \ln p_{js}}, \tag{6}$$

where $\mathrm{sc}\,(j,s)$ denoted the share of factor j over the total cost: $\sum_j \mathrm{sc}\,(j,s) = 1$.

Combining expression (6) with the cost function (4), we obtain

$$\mathrm{sc}\,(j,s) = \phi_j + \sum_i \beta_{ij} \ln(p_{is}) + \lambda_{jy} \ln(y_s) + \eta_{js} t. \tag{7}$$

The following conditions of homogeneity of degree one of the cost function are imposed:

$$\begin{aligned} \sum_i \phi_i &= 1, & \sum_i \lambda_{iy} &= 0, \\ \sum_i \eta_{is} &= 0, & \sum_i \beta_{ij} &= 0. \end{aligned} \tag{8}$$

Taking account conditions in (8) and the symmetry of matrix $\mathbf{B}$, we differentiate the system of equations in (7) as follows:

$$\Delta\,\mathrm{sc}\,(j,s) = \sum_i \beta_{ji}\,\Delta \ln\left(\frac{p_{js}}{p_{is}}\right) + \lambda_{js}\Delta \ln(y_s) + \eta_{js} + e_{js}. \tag{9}$$

Expression (9) defines a system of six equations for j =$\{h,\ m,\ \ell,\ hard,\ com,\ soft\}$, where the seventh expression for $j = non\text{-}ict$ is redundant. The term e_{js} represents an error component with the following structure:

$$e \sim \mathcal{N}_{(S\times 6)}\left(\mathbf{0}, \mathbf{I}_S \otimes \Omega\right).$$

Ω is a (6×6) symmetric positive definite matrix, $\mathbf{I}_s$ is the identity matrix, and $\otimes$ is the Kronecker operator. We also assume no serial correlation, $E\left(e_{ist}e_{jrt-\tau}\right) = 0$, with $\tau \geq 1$, for $i,j \in \{h, m, \ell, hard, com, soft\}$, and for any pair of sectors (s,r). This specification implies that equations in (9) can be estimated using generalized least squares. We correct for potential heteroskedasticity and serial correlation.

3.2 Elasticities

Expression (9) is exploited to calculate several elasticities. For sector s, let us denote ε_{ij}^{s} the cross elasticity of input i with respect to the price of input j, and denote ε_{ii}^{s} the demand elasticity of input i (own-price elasticity). After some algebra, these two elasticities can be written as

$$\varepsilon_{ji}^{s} = \frac{\beta_{ij}}{\mathrm{sc}\,(j,s)} + \mathrm{sc}\,(i,s), \text{ for } i \neq j, \tag{10}$$

$$\varepsilon_{ii}^{s} = \frac{\beta_{ii}}{\mathrm{sc}\,(i,s)} + \mathrm{sc}\,(i,s) - 1. \tag{11}$$

The Allen-Uzawa partial elasticity of substitution between inputs i and j, σ_{ij}^{s}, can be written as:[3]

$$\sigma_{ij}^{s} = \frac{\beta_{ij}}{\mathrm{sc}\,(i,s)\,\mathrm{sc}\,(j,s)} + 1. \tag{12}$$

If β_{ij} were not statistically significant, the elasticity of substitution would tend to unity. Therefore, in the forthcoming econometric analysis, we construct a test where the elasticity of substitution σ_{ij} is equal to one under the null hypothesis.

Once these three elasticities are estimated, we aggregate them across sectors using the nominal gross value added (GVA_s^{nom}) as the weighting factor:

$$\varepsilon_{ji} = \sum_{s} \mathrm{sv}\,(s)\,\varepsilon_{ji}^{s}, \quad \varepsilon_{ii} = \sum_{s} \mathrm{sv}\,(s)\,\varepsilon_{ii}^{s}, \quad \sigma_{ji} = \sum_{s} \mathrm{sv}\,(s)\,\sigma_{ji}^{s}, \tag{13}$$

with $\mathrm{sv}\,(s)$ being the GVA share:

$$\mathrm{sv}\,(s) = \frac{GVA_s^{nom}}{\sum_s GVA_s^{nom}}.$$

In what follows, a pair of inputs (i,j) will be classified as complementary (substitutive) whenever we observe the cross elasticity or the substitution elasticity to be both negative, $\varepsilon_{ji}^{s} < 0$, $\sigma_{ij}^{s} < 0$ (positive, $\varepsilon_{ji}^{s} > 0$, $\sigma_{ij}^{s} > 0$). From (10) and (12), note that

$$\varepsilon_{ji}^{s} = \mathrm{sc}\,(i,s)\ \sigma_{ij}^{s}.$$

[3]Blackorby and Russell (1989) argue that the Allen-Uzawa partial elasticity of substitution does not provide an accurate measure of the isocuant curvature, and recommend to use the elasticitity of substitution proposed by Moroshima (1967): $\varepsilon_{ji}^{s} - \varepsilon_{ii}^{s}$.Morishima's elasticities of substitution are given in Appendix A.

This condition guarantees no incongruences in our criterion to identify complementary or substitutive pairs of inputs.

3.3 Prices

Firstly, we present evidence on the evolution of wages and the user cost of the different capital assets.

Wages of the three categories of workers and for each sector are obtained using data from the EU KLEMS database, taking account of the labor composition effects, due to age and sex effects (the composition for age and gender is fixed in those of 1980). EU KLEMS provides information to calculate wages for at least eighteen categories of workers: three educational levels, three age intervals (less than 29, between 29 and 50, and more than 50 years), and sex. We calculate the average hourly wage for the eighteen workers ($3 \times 3 \times 2$). The average hourly wage for the three skille levels is the weighted average through age and sex.

Let q_{jt} denote the acquisition price of one unit of asset j at time t, using the EU KLEMS implicit deflator of investing in asset j, and let R_{jst} denote the (nominal) rental price for this asset. The rental price of asset j has been calculated as

$$R_{jst} = q_{jst} \left(i_t + \delta_{js} - \Delta \ln q_{jst} \right), \tag{14}$$

where i_t denotes the nominal interest rate: $i_t = r_t + \pi^e_{t,t+1}$, where r_t is the real interest rate and $\pi^e_{t,t+1}$ is the expected rate of inflation. We take a constant real interest rate, $r_t = 4\%$. For the expected inflation rate $\pi^e_{t,t+1}$, we use a centered moving average, using the percentage variation of the CPI. δ_{js} denotes the EU KLEMS depreciation rates of asset j.[4]

Figure 2 reports the evolution of wages W_j ($j \in \{h, m, \ell\}$) and rental prices of capital R_j, ($j \in \{ICT, non\text{-}ICT\}$), aggregated across sectors (all first observations have been normalized to one). Figure 2.a reflects two opposing trends in the relative wage of qualified workers with respect to medium and low-skill workers. For all sectors, from 1980 until the mid-1990s, the wage gap between high-skill and medium-skill workers grew, W_{hst}/W_{mst}, while the wage gap between high-skill workers and low-skill workers, $W_{hst}/W_{\ell st}$, fell. The wage gap between medium and low-skill workers, $W_{mst}/W_{\ell st}$, also fell from 1980 until the early 1990s. From 1995 onward, this gap has

[4] Both R_{jst} and δ_{js} are subindexed by the sector code, s: As capital is a portfolio of physical assets, the rental price of capital may change across sectors.

remained stable, and the wage of high-skill workers fell relative to the other two categories, as their wages began to evolve evenly.

Research in this area is inconclusive about the patterns governing this relative wage across countries, which can be accounted for by changes in relative supply or demand (Acemoglu, 2003). Alternative explanations point to differences in labor market institutions, market power raised by the labor unions, or the degree of globalization of these economies. Christopoulou, Jimeno and Lamo (2010) find an increase in the wage gap for Germany, the Netherlands, Greece, Italy and Belgium. By contrast, wage dispersion falls in Hungary, Ireland and Spain (in line with our evidence). In countries where a strong increase in the supply of skilled workers was observed, the relative wage either fell or remained stable. Verdugo (2012) documents a decline in wage dispersion in France from 1964 to 2008. The major reduction in wage inequality is found after the increase in the supply of skilled workers which, as is the case in Spain, occurred somewhat later than in English-speaking countries.

For Spain, Felgueroso and Jiménez-Martín (2009) find a fall in the wage premium for all levels of education between 1995-2006. There are two factors accounting for this decrease: First is the pattern of production, which tends to be too specialized in low productivity sectors, such as Construction or Real Estate services, identified as low intensive ICT users; second is the rise in the occupational mismatch of skilled workers, (i.e. workers with tertiary education employed in jobs where their skills are not needed), largely due to the increase in the supply of skilled workers. Hidalgo (2010) estimates that a large fraction in the decrease of the wage gap during the 1990s can be accounted for by the relative increase in the supply of skilled workers. Felgueroso, Hidalgo and Jiménez-Martín (2014) show that the increasing share of mismatched skilled workers and the falling relative return to experience between skilled and non skilled workers help to explain the fall in the wage skill premium during this period. Using Social Security records from 1995 to 2002, Izquierdo and Lacuesta (2012) show that changes in the return to education and tenure reduced this wage inequality while changes in the composition of the labor force increased it. By contrast, Pijoan and Sánchez (2010), find that the wage premium of skilled workers was relatively stable until the mid-90s, and steadily decreased.

Figure 2.b presents the user cost capital. Between 1980-1995, the cost of ICT assets increased more slowly than that of the non-ICT assets. From 1995 onwards, the cost of ICT assets fell in absolute terms and relative to the cost of non-ICT assets. The cost of ICT also fell compared with that of the three types of workers.

[**Figure 2 here**]

4 Results

Elasticities are reported in Tables 4, 5 and 6. These elasticities are the weighted average through 1980-2005, and across sectors (see (13)). The upper panel in Table 4 reports the own-price elasticities of demand (ε_{ii}, values through the diagonal), and the cross elasticities (values outside the diagonal, ε_{ji}). The lower triangle below the diagonal reports the cross elasticities of input j with respect to the price of i, ε_{ji}, and the upper triangle reports the corresponding ε_{ij}. The lower panel reports the Allen-Uzawa elasticities of substitution, σ_{ij}.[5] Figures in brackets are t-student statistics. For the elasticities of substitution the null hypothesis is the elasticity equal to one. Standard deviations have been calculated following Anderson and Thursby (1986). Tables 5 and 6 present the same information than Table 4, for the 8 sectors classified as intensive users of ICT, and for the remaining 16 non intensive sectors of ICT (this classification follows Mas and Quesada (2006), and can be viewed in Table 2).

In view of Tables 4, 5 and 6, we reach the following conclusions. First, ICT assets complement more hours worked the higher the skill is. High skill workers and ICT assets appear complementary in all sectors, as shown by the negative cross elasticities $\varepsilon_{h,j} < 0$, and the Allen-Uzawa elasticities of substitution $\sigma_{h,j} < 0$, for $j = hard,\ com,\ soft$. On the contrary, they are substitutive for non-ICT capital assets, $\sigma_{h,non-ict} = 2.042$. All these estimates are statistically significant. Highly skilled workers and medium (or low) skill workers present substitutive relationship ($\sigma_{h,m} = 0.300$, $\sigma_{h,\ell} = 1.158$). These estimates, though, are not statistically significant, implying that we cannot reject the null hypothesis that the substitution elasticity is unitary.

Analogously, the medium-skill workers are substitutive with non-ICT capital, $\sigma_{m,non-ict} = 2.044$ (Table 4), and complementary to communication networks: $\sigma_{m,com} = -0.378$ (Table 5), and $\sigma_{m,com} = -3.909$ (Table 6). In the non intensive sectors, medium-skill workers are complementary to software licences: , $\sigma_{m,soft} = -6.478$ (Table 6).

Second, in view of the own-price elasticities (ε_{ii}-values across the diagonal), the demand for medium and high skill workers is more inelastic than the demand for low skill workers, which helps explain the high variability in the employment of these latter in the Spanish labor market. As we will see in the following Section, low skill workers tend to be employed under temporary contracts, with low and certain severance pays. By contrast, skilled workers tend to be hired under permanent

[5] For an estimate of the Morishima elasticities see Appendix B.

contracts. During the early months of a recession, due to wage rigidities, firms make internal adjustments by firing these temporary (lowly skilled) workers. Such a dual structure might have its origins in the labor market reform of 1984, which allowed firms to hire workers under a temporary contract characterized by lower and clearly defined firing costs, relative to tenure contract workers. The temporary rate increased beginning in the mid-1980s onward, and mostly in Agriculture and the Construction sector. Indeed, this has been specially relevant during the housing price boom that took place between 1999-2008, where a quarter of total male hours worked were employed in the Construction sector. The sharp drop in the rate after the start of the great Recession can be explained by firms eliminating temporary jobs as a real adjustment mechanism.

Third, when we account for the intensity through which ICT assets are used in a sector, there are not *qualitative* differences in these elasticities, as is shown in Tables 5 and 6. It is worth mentioning, however, that there are indeed *quantitative* differences. In Appendix C we report the results for the hypothesis test of equality of elasticities in Tables 5 and 6. The null hypothesis of equality of elasticities is rejected in most of the cases.

Fourth, low skill workers are substitutive of all other factors. The elasticities are statistically significant in every case, regardless of the sector. This result, together with the evolution of relative wages shown in Figure 2.a, helps to explain why the employment rate for this type of worker fluctuated more than that of any other group (between 1980 and 2005, the fraction of low-skill workers fell by 33%).

Fifth, ICT capital assets are complementary among themselves, and substitutive of the non-ICT assets. Since the 1970s, the supply of skilled workers in Spain has grown. This caused a drop in the relative wage with low-skill workers, W_h/W_ℓ. Such a fall is related to the substitution relationships found here, inducing a number of adjustments within the intensive and non-intensive sectors of ICT. Thus, the complementarity between ICT assets and skilled labor, together with the lower user cost, fostered the employment of skilled workers in the few ICT intensive sectors.

Figure 3 shows the evolution of elasticities over time. In each of the sub-graphs a dotted line has been inserted at value one, as a reference of the statistical significance (unit elasticity is the null hypothesis). The shadowed area represents a 95% confidence band (Anderson and Thursby, 1986). The downward-sloping elasticities for highly skilled workers and non-ICT assets ($\sigma_{h,non-ict}$, Figure 3.6) indicate a fall in substitutability between these factors. High skill workers are complementary with ICT assets, for which the values of these series appear to approach zero gradually going from negative values towards zero (i.e. tending to perfect Leontieff complementarity, Figures 3.3

to 3.5). In the case of medium skill workers, elasticities tend towards complementarity with ICT assets (Figures 3.8 to 3.10), and to substitution with non-ICT assets (Figure 3.11). Finally, for low skill workers the series are upward-sloping (Figures 3.12 to 3.15). In summary, substitutability fell for skilled workers and rose for lowly skilled ones.

These results meet those for other countries: As for the US from 1963 to 1992, Krusell, Ohanian, Ríos-Rull and Violante (2000) have found an elasticity of substitution of 0.67 for skilled labor and capital equipment (complementary), and of 1.67 for unskilled labor and capital equipment. For Germany from 1974 to 1998, Falk and Koebel (2004) find similar values to ours, albeit evidence of substitutability between unskilled workers and ICT assets is only found in the non manufacturing sectors. For France from 1994 to 1997, Biscourp et al (2002) find an elasticity of -1.7 between skilled workers and hardware, and 3.5 for unskilled workers. For Japan from 1980 to 1998, Kurokawa et al. (2004) have estimated substitution elasticities between ICT and young skilled and unskilled workers. Their results range from -22.26 to -0.58 for young skilled workers and ICT (complementarity), and between 1.32 and 10.44 for unskilled ones (substitutability). O.Mahony, Robinson and Vecchi (2008) study the cases of the U.S., the U.K., France and Germany and reach similar evidence to the present paper.

[**Tables 4-6 and Figure 3 here**]

5 A regression analysis

A large body of research has looked at the question of what the key drivers of aggregate efficiency are, as measured by TFP, and technology adoption. One approach in the literature views institutions as being responsible for the downturn in productivity and the overall lag in ICT adoption (Gust and Márquez, 2004). For Spain, labor market institutions and regulatory practices are often mentioned as producing transaction costs and barriers to technology adoption and human capital accumulation. This view helps to explain the gap in technology. For instance, an increase in the power of unions to set collective wages can generate disincentives for firms to invest in new technologies. On the other hand, an alternative approach seeks to explain these facts as due to the change in the sectorial composition after the Spain's EEC access in 1986: the output share of non tradable sectors increased. This change can produce different incentives to use new technologies across sectors, and helps to explain differences across sectors.

Institutions and the technological gap. After the advent of democracy in the mid 70s, several policies were gradually introduced in order to strengthen employment protection. Two labor market reforms, in 1984 and 1994, have overprotected workers with tenured contracts, while temporary workers ended up underprotected. Although the standards of both reforms were aimed at introducing flexibility, in practical terms they have accounted for a duality problem in the Spanish labor market: while severance pays for temporary workers is low and certain, it is high and subject to a huge risk of litigation for tenured workers. Firms have many incentives to rely on temporary workers during booms and to dismiss them during the early quarters of recessions. Dolado and Stucchi (2008) argue that workers' effort depends on their perception about firms' incentives to convert temporary contracts into permanent ones. Using manufacturing firm level data in Spain from 1991 to 2005, they conclude that high conversion rates increase firms' productivity while high shares of temporary contracts decrease it. Both effects are statistically significant. In this direction, Boldrin, Conde and Díaz-Giménez (2010) and Rodríguez-López and Solís-García (2014) suggest that the presence of a dual labor market overprotective of permanent workers can account for the potential inefficiencies in the process of wage setting, and has a crucial role in the propagation of business cycles in Spain.

Access to international trade. Spain's EEC entry in 1986 was followed by a sectorial change and a specialization in non tradable activities, in the vein predicted by the Neoclassical model. These activities, such as construction or real estate services have accounted for a considerable fraction of aggregate production during this period. Delgado, Fariñas, and Ruano (2002), using firm level data for Spain, found that productivity tend to be sensibly higher in exporting firms.

We use several institutional indicators related to these approaches to seek for significant correlations with sectorial TFP and the ICT investment. In particular, we will use the following regressors: Two indicators of the degree of centralization and coordination of the collective bargaining (Nickel, 2006), the index of employment protection proposed by Allard (2005), the sectorial temporary rates (i.e. the ratio of the number of wage earners under a fixed-term contract relative to the total number of workers), and the index of freedom to trade internationally proposed by Gwartney, Lawson and Hall (2013). Appendix C presents a through description of these regressors. The dependent variables are the growth rate in sectorial efficiency, $\Delta \log(TFP_{s,t})$, and the change in the ICT investment share, measured as

$$\Delta \left[\frac{IN_{ict,s,t}}{\sum_j IN_{j,s,t}} \right],$$

where $IN_{j,s,t}$ denotes the nominal investment in asset j. The results of the regressions are presented in Tables 7 and 8.

In columns (1) and (2) of Table 7, we present the regression for $\Delta \log (TFP_{s,t})$ on previous indicators. All variables, including the temporary rate, have been differenced. As long as centralization and coordination of the collective bargaining have evolved evenly through the labor market reforms in Spain, we include them in the regressions alternatively, to avoid multicollinearity. The results indicate that sectorial TFP increases in response to a decrease in the centralization or the coordination. Allard's index is negatively correlated and significant: an increase in employment protection leads to a fall in sectors' efficiency. The change in the temporary rate and the freedom to trade are both positive but not statistically significant. In columns (3) and (4) of Table 7 we use the level of the temporary rate rather than the change of it. This variable, joint with Allard's index, is negatively correlated and significant, in the vein of the findings of Dolado and Stucchi (2008). The temporary rate increased 23 percentage points during the period considered. While these fixed-term contracts tend to be associated with low skilled workers, according to the regression results, the 23% increase produced a TFP deceleration of 1.84%.

The same strategy is followed for the change in the ICT investment share in Table 8. Again, we find that variables associated with labor market institutions are all significant and negatively correlated with ICT investment. The sectoral temporary rates (in both differences and levels) are negatively correlated with the ICT share. The 23% temporary rate overall increase accounts for a reduction in the ICT investment share of 5.87%. Interestingly, the freedom to trade internationally is negatively correlated and significant. In fact, most of the ICT intensive sectors reported in Table 2 refers to non tradable activities. The increase in openness of the Spanish economy, mainly after 1986, apparently stimulate the ICT investment in these few sectors to reap the productivity and efficiency benefits from the ICT.

In summary, in view of these results, together with those in Table 1, these institutional disruptions help explain the Spanish delay in ICT investment and the poor evolution in TFP, as compared to the rest of European partners and the US. The globalization process that took place after Spain's access to the EEC and the early adoption of the Euro in 1999, led Spanish policy-makers to implement labor market reforms and fiscal reforms that induce a downturn in productivity. This finding is analogous to that of McMillan and Rodrik (2011) for Latin American countries, where the structural change which occurred after globalization during the nineties has exacerbated the costs of adopting misleading policies, mainly focused on the structural change within industries, but often neglecting the reallocation of resources between sectors. For a discussion on how the reallocation of factors across sectors may respond to measured differences in TFP across countries and sectors, see Restuccia and Rogerson (2014) and Timmer and de Vries (2009).

[**Tables 7-8 here**]

6 Conclusions

Spain faces a severe productivity problem that dates back to the mid 80s. Only a small number of sectors, accounting for one third of gross output, have adopted the ICT assets intensively (Mas and Quesada, 2006). Skilled workers, i.e. workers with college and higher education, have been mainly employed in these few sectors. Compared with other OECD economies, Spain has a low ICT investment ratio.

Using the EU KLEMS dataset, for the period 1980-2005, the bulk of the adjustment in hours worked favored firstly the employment of workers with medium education (+21%), i.e. workers with only secondary education, and secondly skilled workers (+12%), at the cost of less employment for low skill workers. These adjustments have been produced within sectors. The adjustments between sectors, however, did work until the mid 90s, a period that coincides with sound reforms in the Spanish industrial public sector and two labor market reforms in 1984 and 1994. After these reforms, the inter sector mobility of workers apparently collapsed. While the wage gap increased in favor of the skilled workers until the mid 80s, it levelled out or even decreased during the 90s. Related studies conclude that this evolution in the relative wages in Spain was guided by labor supply side forces rather than labor demand displacements.

The acquisition prices of both the ICT assets and the non ICT assets have decreased across this period. This has happened in Spain and worldwide. The rental price and user cost of capital have also been reduced. Such a fall in the cost of capital reflects technological improvements embodied in the capital assets (Cummins and Violante, 2002). The technological progress has been remarkably high within the ICT assets (hardware, software, information systems, and communication networks), and they account for a considerable fraction of productivity growth in countries such as Germany, Japan and the US (Rodríguez-López and Torres, 2012).

We find empirical support for the skill-complementarity hypothesis: skills complement technology. Furthermore, we also conclude that the capital-skill complementarity still holds across sectors. For any pair of inputs that appears complementary (substitute) in a given sector, it is so in any other sector. Importantly, the complementarity between ICT and labor increases with the skill level of workers.

The problem of productivity and ICT adoption affects most activities in the Spanish economy.

We address this issue using a regression analysis in order to search which institutional factors are likely behind the downturn in TFP after 1995 and the ICT gap with respect to other European countries. The duality in the Spanish labor market caused by an overprotection of tenured workers appears as a key distortion in explaining these two issues.

References

[40] Acemoglu, D. (2003): Cross-Country Inequality Trends. *Economic Journal* 113, 121-149.

[40] Allard, Gayle (2005) Measuring job security over time: in search of a historical indicator for employment protection legislation. *Instituto de Empresa Working Paper WP* 05-17.

[40] Anderson and Thursby (1986): Confidence Intervals for Elasticity Estimators in Translog Models. *The Review of Economics and Statistics* 68(4), 647-656.

[40] Autor, D. (2002): Skill Biased Technical Change and Rising Inequality: What is the Evidence? What are the Alternatives? Mimeograph.

[40] Berman, E. and J. Bound, and Z. Griliches (1994): Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures. *The Quarterly Journal of Economics* 109, 367-97.

[40] Biscourp, P, B. Crépon, T. Heckel, and N. Riedinger (2002): How do firms respond to cheaper computers? Microeconometric evidence for France based on a production function approach. Série des documents de travail de la Direction des Etudes et Synthèses Économiques, Institut National De La Statistique Et Des Études Économiques, Paris.

[40] Boldrin, M., J.I. Conde-Ruíz, and J. Díaz-Giménez (2010) Eppur si muove! Spain: growing without a model. *FEDEA Documento de Trabajo* No. 2010-11.

[40] Colecchia, A. and P. Schreyer (2002): ICT investment and economic growth in the 1990's: Is the United States a unique case? A comparative study of nine OECD countries. *Review of Economic Dynamics*, 5(2), 408-442.

[40] Christopoulou, R., J.F. Jimeno and A. Lamo (2010): Changes in the wage structure in EU countries, European Central Bank, Working Paper Series No 1199

[40] Cummins, J.G. and G.L.Violante (2002) Investment-specific technical change in the U.S. (1947–2000): Measurement and macroeconomic consequences. *Review of Economic Dynamic* 5, 243–284.

[40] Delgado, M., J. Fariñas, and S. Ruano (2002) Firm Productivity and Export Markets: a Non-Parametric Approach. *Journal of International Economics*, 57(2), 397–422.

[40] Dolado, J. J. and R. Stucchi (2008): Do Temporary Contracts Affect TFP? Evidence from Spanish Manufacturing Firms. IZA DP No. 3832.

[40] Falk, M., and B.M. Koebel (2004): The impact of office machinery, and computer capital on the demand for heterogeneous labour. *Labour Economics* 11, 99–117.

[40] Felgueroso, F. and S. Jiménez (2009): "The New Growth Model. How and with Whom?", *DT FEDEA 39-2009*.

[40] Felgueroso, F., M. Hidalgo-Pérez and S. Jiménez-Martín (2014): The puzzling fall in the wage skill premium in Spain, forthcoming in *Manchester School*.

[40] Flanagan, Robert J. (1999) Macroeconomic performance and collective bargaining: an international perspective. *Journal of Economic Literature* 37, 1150-1175.

[40] Goldin, C. and L. F. Katz (1998) The Origins of Technology-Skill Complementarity. *Quarterly Journal of Economics* 113, 693-732.

[40] Gust, C. and J. Márquez (2004): International comparisons of productivity growth: the role of information technology and regulatory practices. *Labour Economics* 11, 33– 58

[40] Gwartney, J., R. Lawson, and J. Hall (2012): Economic Freedom of the World: 2012 Annual Report. Vancouver, B.C: Fraser Institute.

[40] Hidalgo-Pérez, M. (2010): A Demand-Supply Analysis of the Spanish Education Wage Premium in the 1980s and 1990s. *Revista de Economía Aplicada* 54, 57-78.

[40] Izquierdo, M., and A. Lacuesta (2012): The contribution of changes in employment composition and relative returns to the evolution of wage inequality: the case of Spain. *Journal of Population Economics*, 25(2), 511-543.

[40] Jimeno, J. F., E. Moral, and L. Saiz (2007) Structural breaks in labor productivity growth: the United States vs. the European Union. *Banco de España* WP 0625.

[40] Jorgenson, D. W. (2001): Information Technology and the US Economy. *American Economic Review* 91(1), 1-32.

[40] Krusell, P., L. Ohanian, V. Rios-Rull, and G. Violante (2000): Capital Skill Complementary and Inequality: A Macroeconomic Analysis. *Econometrica* 68(5), 1029-1053.

[40] Kurokawa, F., K. Minetaki, K. G. Nishimura, and M. Shirai (2004). Effects of Information Technology and Aging Work Force on Labor Demand and Technological Progress in Japanese Industries: 1980-1998. The Economics of Aging Population: Macroeconomic Issues (ESRI Studies Series on Aging), 75-156.

[40] Machin, S and J. Van Reenen (1998): Technology and Changes in Skill Structure: Evidence from Seven OECD Countries. *The Quarterly Journal of Economics* 113(4), 1215-1244.

[40] Mas, M. and J. Quesada (2006): The Role of ICT in the Spanish Productivity Slowdown. Documentos de Trabajo de la Fundación BBVA 2006-5.

[40] McMillan, M. S., and Rodrik, D. (2011): "Globalization, structural change and productivity growth". *NBER working paper* 17143.

[40] Nickell, W. (2006): The CEP – OECD institutions data set (1960-2004). *Centre for Economic Performance Discussion Paper* No. 759.

[40] Ochel, W. (2000): Collective bargaining (centralization and coordination). Ifo Institute, mimeo.

[40] O'Mahony, M., C. Robinson and M. Vecchi (2008): The Impact of ICT on the Demand for Skilled Labour: A Cross-Country Comparison. *Labour Economics* 15(6), 1435–1450.

[40] Pijoan, J. and V. Sánchez (2010): Spain is Different: Falling Trends of Inequality, *Review of Economic Dynamics*, vol. 13(1), 154-178.

[40] Restuccia D. and R. Rogerson (2013): "Special issue: Misallocation and Productivity", Review of Economic Dynamics 16, 1-10.

[40] Rodríguez-López, J. and J.L. Torres (2012) "Technological sources of productivity growth in Japan, the U.S. and Germany". *Macroeconomic Dynamics* vol. 16 No. 1, 133–150.

[40] Rodríguez-López, J. and M. Solís-García (2014): Accounting for Spanish business cycles. Forthcoming in *Macroeconomic Dynamics.*

[40] Stiroh, K: (2002): Information technology and U.S. productivity revival: What do the industry data say? *American Economic Review*, vol. 92 (5), 1559-1576.

[40] Timmer, M. P. and G. J. de Vries (2009): "Structural Change and Growth Accelerations in Asia and Latin America: A New Sectoral Data Set". *Cliometrica*, vol 3 (2) , 165-190.

[40] Timmer, M. P., G. Ypma and B. van Ark (2003): IT in the European Union: Driving Productivity Divergence? *GGDC Research Memorandum GD-67*.

[40] Verdugo, G. (2012). The great compression of the wage structure in France 1969-2008. *WP Banque de France A.2*.

[40] Welch, B. L. (1947): The generalization of "Student's" problem when several different population variances are involved. *Biometrika* 34 (1–2): 28–35.

7 Tables

Table 1: TFP and ICT investment across countries

	TFP growth			ICT gross investment (%)		
	1991-1995	**1996-2000**	**2001-2005**	**1991-1995**	**1996-2000**	**2001-2005**
Austria	1.03	0.94	0.26	7.8	9.0	10.3
Denmark	0.78	-0.25	-0.28	15.8	15.4	16.8
Finland	0.86	1.95	0.84	12.6	13.8	14.0
Germany	0.70	0.70	0.38	9.0	10.2	11.1
Italy	1.14	-0.12	-0.66	9.3	10.7	9.2
Japan	-0.23	0.04	0.43	10.0	13.2	12.5
Netherlands	0.02	0.46	0.46	11.5	13.4	14.1
Spain	0.13	-0.78	-0.81	9.3	10.6	8.9
Sweden	0.94	0.62	1.17	17.2	20.4	19.4
United Kingdom	1.33	0.31	0.33	15.5	20.8	18.7
United States	0.04	0.41	1.07	17.0	20.5	19.4

Source: EU KLEMS and own calculations

Table 2: Percentage of hours worked according to skill

	1985			1995			2005		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
ICT intensive users	17.7	17.8	64.5	24.6	28.9	46.5	33.6	35.5	30.8
Pulp, paper, printing and publish.	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Electric, electronic, optic equip.	8.9	22.1	69.0	15.6	37.8	46.6	24.1	45.2	30.7
Energy and water	12.5	18.3	69.2	19.6	32.2	48.2	33.0	37.8	29.2
Transp. and communic. services	6.0	14.1	79.9	9.5	25.7	64.7	17.0	37.8	45.3
Financial and banking services	15.5	35.8	48.7	29.8	44.5	25.7	50.3	39.0	10.6
Business services	25.1	22.1	52.8	30.4	29.1	40.5	39.8	32.1	28.2
Private health & social services	43.6	12.4	44.0	46.3	25.0	28.7	49.0	34.3	16.7
Other community services	7.2	14.0	78.8	14.1	26.3	59.6	24.2	36.9	38.9
ICT non-intensive users	7.5	7.8	84.7	10.7	18.6	70.7	15.3	30.2	54.5
Food, drink and tobacco	3.3	8.3	88.5	5.7	18.0	76.3	11.1	29.1	59.8
Textiles, leather and footwear	2.8	7.1	90.1	3.3	13.8	82.9	6.4	25.8	67.8
Wood and cork products	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Oil refin., coke and nuclear fuel	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Chemicals	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Rubber and plastics	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Other non-metallic mineral	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Fabricated metal products	5.8	13.0	81.2	8.9	24.8	66.3	15.0	33.9	51.1
Machinery and mechanical eq.	7.4	20.5	72.1	7.4	32.9	59.7	13.6	46.5	39.9
Transport equip. manufact.	4.2	14.2	81.6	8.2	29.6	62.2	17.0	41.7	41.3
Miscellaneous manufact.	2.9	7.7	89.5	2.8	14.5	82.7	7.6	28.9	63.6
Construction	3.7	5.3	91.0	4.3	15.3	80.4	7.7	25.1	67.2
Wholesale and retail trade; Repairs	3.5	11.3	85.2	6.5	25.0	68.5	12.1	38.7	49.2
Hotels and catering	1.6	6.6	91.8	3.4	17.5	79.1	9.1	34.5	56.4
Real estate	25.1	22.1	52.8	30.4	29.1	40.5	39.8	32.1	28.2
Private education	74.3	8.1	17.6	74.4	11.8	13.8	77.9	13.0	9.1

Source: EU KLEMS and own calculation

Table 3: Decomposition in the variation of hours worked

	High-skill workers			Medium-skill workers		
	Between	Within	Total effect	Between	Within	Total effect
1980-2005	3.48	8.68	12.16	-1.61	22.66	21.06
1980-1985	1.22	0.81	2.03	-0.18	4.02	3.84
1986-1990	0.77	1.03	1.81	-0.53	6.59	6.06
1991-1995	1.13	1.49	2.63	-0.38	4.71	4.33
1996-2000	-0.08	2.75	2.67	-0.45	5.64	5.19
2000-2005	0.45	2.58	3.03	-0.07	1.71	1.64

Source: EU KLEMS and own calculations.

Table 4: Elasticities. All sectors

Demand and cross elasticities $(\varepsilon_{ii}, \varepsilon_{ji})$							
	Factor i						
	Worker (education level)			Capital			
Factor j	high	medium	low	hardware	comm	software	non ict
high	-0.792***	0.05	0.471**	-0.032**	-0.024**	-0.035**	0.362***
	[-3.54]	[0.208]	[2.059]	[-2.39]	[-2.03]	[-2.44]	[12.54]
medium	0.063	-0.797*	0.332	0.045**	-0.045*	0.040*	0.362***
	[0.233]	[-1.69]	[1.279]	[2.037]	[-1.80]	[1.786]	[19.28]
low	0.245**	0.135	-0.842***	0.046***	0.043***	0.040***	0.333***
	[2.206]	[1.002]	[-5.49]	[4.543]	[5.088]	[4.135]	[28.16]
hardware	-0.605**	0.660*	1.656***	-1.398***	-0.389***	-0.399***	0.475*
	[-2.15]	[1.869]	[4.134]	[-9.21]	[-2.75]	[-2.81]	[1.854]
comm	-0.249*	-0.359**	0.845***	-0.212**	-0.149	-0.216***	0.340**
	[-1.81]	[-2.20]	[5.905]	[-2.56]	[-0.41]	[-2.78]	[2.433]
software	-1.090**	0.971*	2.434***	-0.665***	-0.661***	-1.663***	0.675
	[-2.53]	[1.677]	[4.764]	[-2.63]	[-2.82]	[-6.97]	[1.576]
non ict	0.432***	0.338***	0.765***	0.030**	0.040**	0.026	-1.631***
	[11.72]	[21.78]	[27.31]	[1.997]	[2.268]	[1.507]	[-23.0]

Allen-Uzawa elasticities σ_{ij}							
	Factor i						
	Worker (education level)			Capital			
Factor j	high	medium	low	hard	comm	software	non ict
high	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
medium	0.3	-	-	-	-	-	-
	[0.54]	-	-	-	-	-	-
low	1.158	0.815	-	-	-	-	-
	[0.300]	[0.22]	-	-	-	-	-
hardware	-2.856***	3.992	4.067***	-	-	-	-
	[-2.91]	[1.401]	[3.117]	-	-	-	-
comm	-1.174***	-2.170***	2.075***	-18.898***	-	-	-
	[-3.35]	[-3.22]	[3.059]	[-2.69]	-	-	-
software	-5.148***	5.871	5.980***	-59.229***	-32.139***	-	-
	[-3.03]	[1.391]	[3.968]	[-2.68]	[-2.90]	-	-
non ict	2.042***	2.044***	1.879***	2.68	1.919	3.807	-
	[5.983]	[11.13]	[12.78]	[1.252]	[1.086]	[1.111]	-

Boostrap estimations using 50 repetitions and samples of 250 observations. *, **, and *** denote statistical significance at the 10%, 5% and 1% levels.Figures in brackets are $t-$students statistics.

Table 5: Elasticities. ICT intensive sectors

Demand and cross elasticities $(\varepsilon_{ii}, \varepsilon_{ji})$

Factor i

	Worker (education level)			**Capital**			
Factor j	high	medium	low	hardware	comm	software	non ict
high	-0.641**	0.175	0.256	-0.035	-0.013	-0.043*	0.301***
	[-2.20]	[0.526]	[0.866]	[-1.59]	[-0.76]	[-1.72]	[16.06]
medium	0.269	-0.802	0.025	0.138***	-0.083**	0.131***	0.323***
	[0.528]	[-1.07]	[0.048]	[3.602]	[-2.11]	[3.028]	[9.114]
low	0.238	0.015	-0.831**	0.066***	0.085***	0.059***	0.369***
	[1.155]	[0.050]	[-2.53]	[3.914]	[5.865]	[2.788]	[14.17]
hardware	-0.519	1.334***	1.059***	-1.437***	-0.416**	-0.444***	0.423
	[-1.42]	[3.544]	[2.899]	[-7.19]	[-2.39]	[-2.57]	[1.139]
comm	-0.093	-0.378*	0.633***	-0.195**	-0.057	-0.203**	0.294*
	[-0.63]	[-1.73]	[4.140]	[-2.07]	[-0.17]	[-2.49]	[1.687]
software	-1.081*	2.152***	1.592***	-0.757**	-0.736**	-1.764***	0.595
	[-1.89]	[3.299]	[2.711]	[-2.22]	[-2.43]	[-6.02]	[0.940]
non ict	0.463***	0.324***	0.609***	0.044	0.065	0.036	-1.541***
	[14.81]	[11.01]	[14.74]	[0.980]	[1.603]	[1.019]	[-11.1]

Allen-Uzawa elasticities σ_{ij}

Factor i

	Worker (education level)			**Capital**			
Factor j	high	medium	low	hardware	comm	software	non ict
high	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
medium	0.975	-	-	-	-	-	-
	[-0.01]	-	-	-	-	-	-
low	0.863	0.083	-	-	-	-	-
	[-0.18]	[-0.56]	-	-	-	-	-
hardware	-1.882**	7.421***	3.576**	-	-	-	-
	[-2.17]	[3.066]	[2.089]	-	-	-	-
comm	-0.337**	-2.105**	2.136**	-10.512**	-	-	-
	[-2.53]	[-2.56]	[2.202]	[-2.27]	-	-	-
software	-3.922**	11.974***	5.376**	-40.747**	-18.597**	-	-
	[-2.37]	[3.023]	[2.207]	[-2.27]	[-2.56]	-	-
non ict	1.680***	1.803***	2.055***	27 2.36	1.638	3.316	-
	[5.997]	[4.907]	[7.570]	[0.565]	[0.624]	[0.712]	-

Boostrap estimations using 50 repetitions and samples of 250 observations. *, **, and *** denote statistical significance at the 10%, 5% and 1% levels.Figures in brackets are $t-$students statistics.

Table 6: Elasticities. ICT non-intensive sectors

Demand and cross elasticities $(\varepsilon_{\mathbf{ii}}, \varepsilon_{\mathbf{ji}})$

Factor i

	Worker (education level)			Capital			
Factor j	high	medium	low	hardware	comm	software	non ict
high	-0.912**	-0.177	0.750**	-0.037	-0.026	-0.022	0.423***
	[-2.44]	[-0.37]	[2.177]	[-1.30]	[-1.33]	[-1.06]	[8.776]
medium	-0.189	-0.531	0.384	0.007	-0.032	-0.024	0.385***
	[-0.43]	[-0.74]	[0.805]	[0.263]	[-0.97]	[-0.65]	[17.72]
low	0.266	0.127	-0.800***	0.035***	0.020**	0.035***	0.317***
	[1.619]	[0.820]	[-3.72]	[3.154]	[2.274]	[3.291]	[26.74]
hardware	-0.985	0.18	2.644***	-1.470***	-0.469	-0.46	0.561
	[-1.32]	[0.246]	[2.839]	[-6.04]	[-1.40]	[-1.39]	[1.396]
comm	-0.532	-0.62	1.171*	-0.361**	-0.228	-0.362	0.476
	[-1.23]	[-0.89]	[1.737]	[-1.96]	[-0.205]	[-1.44]	[1.540]
software	-1.004	-1.027	4.533***	-0.790*	-0.806	-1.746***	0.839
	[-0.93]	[-0.61]	[3.015]	[-1.90]	[-1.40]	[-3.09]	[1.220]
non ict	0.409***	0.348***	0.862***	0.02	0.022	0.018	-1.678***
	[8.904]	[15.94]	[25.06]	[1.363]	[1.410]	[1.127]	[-21.1]

Allen-Uzawa elasticities σ_{ij}

Factor i

	Worker (education level)			Capital			
Factor j	high	medium	low	hardware	comm	software	non ict
high	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
medium	-1.115	-	-	-	-	-	-
	[-0.82]	-	-	-	-	-	-
low	1.569	0.803	-	-	-	-	-
	[0.587]	[-0.20]	-	-	-	-	-
hardware	-5.802	1.133	5.534**	-	-	-	-
	[-1.55]	[0.028]	[2.326]	-	-	-	-
comm	-3.13	-3.909	2.451	-57.430**	-	-	-
	[-1.63]	[-1.11]	[1.028]	[-2.00]	-	-	-
software	-5.912	-6.478	9.487***	-125.450*	-98.688	-	-
	[-1.09]	[-0.71]	[2.697]	[-1.91]	[-1.41]	-	-
non ict	2.408***	2.192***	1.804***	3.195	2.708	4.777	-
	[5.205]	[8.672]	[11.17]	[0.936]	[0.889]	[0.891]	-

Boostrap estimations using 50 repetitions and samples of 250 observations. *, **, and *** denote statistical significance at the 10%, 5% and 1% levels.Figures in brackets are $t-$students statistics.

Table 7: Total factor productivity growth across sectors in Spain, 1980-2005
Dependent variable is $\Delta\left[\ln\left(TFP_{s,t}\right)\right]$

	(1)	(2)	(3)	(4)
Δ Centralization of collective bargaining	-0.070**		-0.011	
	(0.030)		(0.041)	
Δ Coordination of collective bargaining		-0.140**		-0.022
		(0.060)		(0.082)
Δ Employment protection index	-0.083*	-0.083*	-0.095*	-0.095*
	(0.043)	(0.043)	(0.043)	(0.043)
Δ Temporary rate	0.147	0.147		
	(0.141)	(0.141)		
Temporary rate			-0.080*	-0.080*
			(0.035)	(0.035)
Δ Freedom to trade internationally index	0.002	0.002	0.024	0.024
	(0.091)	(0.091)	(0.087)	(0.087)
Constant	-0.005*	-0.005*	-0.017*	-0.017*
	(0.003)	(0.003)	(0.010)	(0.010)
No. Obs.	750	750	750	750
R^2	0.017	0.017	0.021	0.021

Notes: TFP series per sector are retrieved from EU KLEMS database. The indexes of centralization and coordination of collective bargaining come from Ochel (2000) and Nickell (2006). The index of employment protection is that of Allard (2005). The temporary rate is calculated using the Spanish Current Population Survey (EPA, Encuesta de Población Activa) from Instituto Nacional de Estadística (INE). The index of Freedom to trade internationally is that of Gwartney, Lawson, and Hall (2012).

*, **, and *** denote statistical significance at the 10%, 5% and 1% levels.

Table 8: ICT investment across sectors in Spain, 1980-2005

Dependent variable is Δ[ICT investment share]

	(1)	(2)	(3)	(4)
Δ Centralization of collective bargaining	-0.063***		-0.018	
	(0.014)		(0.020)	
Δ Coordination of collective bargaining		-0.126***		-0.036
		(0.029)		(0.039)
Δ Employment protection index	-0.037*	-0.037*	-0.046*	-0.046*
	(0.020)	(0.020)	(0.021)	(0.021)
Δ Temporary rate	-0.2547***	-0.2547***		
	(0.067)	(0.067)		
Temporary rate			-0.045***	-0.045***
			(0.017)	(0.017)
Δ Freedom to trade internationally index	-0.101**	-0.101**	-0.150**	-0.150**
	(0.043)	(0.043)	(0.042)	(0.042)
Constant	0.000	0.000	0.010**	0.010**
	(0.001)	(0.001)	(0.005)	(0.005)
No. Obs.	750	750	750	750
R^2	0.017	0.017	0.021	0.021

Notes: TFP series per sector are retrieved from EU KLEMS database. The indexes of centralization and coordination of collective bargaining come from Ochel (2000) and Nickell (2006). The index of employment protection is that of Allard (2005). The temporary rate is calculated using the Spanish Current Population Survey (EPA, Encuesta de Población Activa) from Instituto Nacional de Estadística (INE). The index of Freedom to trade internationally is that of Gwartney, Lawson, and Hall (2012).

*, **, and *** denote statistical significance at the 10%, 5% and 1% levels.

A Morishima elasticities of substitution

Table A.1: Morishima elasticities. All sectors

	Factor i						
	Workers (education level)			Capital			
Factor j	high	medium	low	hardware	comm.	software	non ict
high	-	0,847	1,313	1,366	0,125	1,629	1,993
	-	[3,787]	[5,398]	[89,26]	[9,779]	[142,7]	[71,64]
medium	0,856	-	1,173	1,443	0,105	1,703	1,993
	[3,189]	-	[4,089]	[61,45]	[3,876]	[67,59]	[110,9]
low	1,037	0,932	-	1,444	0,192	1,703	1,964
	[10,10]	[5,965]	-	[170,0]	[21,06]	[176,4]	[152,3]
hardware	0,187	1,457	2,497	-	-0,240	1,265	2,106
	[0,663]	[4,189]	[5,420]	-	[-1,55]	[8,369]	[7,161]
comm.	0,544	0,438	1,686	1,186	-	1,447	1,971
	[3,972]	[1,981]	[9,066]	[15,38]	-	[17,45]	[12,26]
software	-0,298	1,768	3,276	0,733	-0,512	-	2,306
	[-0,63]	[2,573]	[5,268]	[3,100]	[-1,96]	-	[4,699]
non ict	1,225	1,135	1,607	1,429	0,189	1,689	-
	[37,02]	[63,63]	[64,84]	[89,92]	[12,21]	[90,11]	-

Boostrap estimations using 50 repetitions and samples of 250 observations
Figures in brackets are $t-$students statistics

Table A.2: Morishima elasticities. ICT intensive sectors

	Factor i						
	Workers (education level)			Capital			
Factor j	high	medium	low	hardware	comm.	software	non ict
high	-	0,977	1,087	1,402	0,044	1,722	1,842
	-	[3,419]	[4,686]	[71,89]	[2,170]	[110,1]	[100,8]
medium	0,910	-	0,856	1,574	-0,026	1,895	1,864
	[1,799]	-	[1,455]	[35,27]	[-0,63]	[42,05]	[64,22]
low	0,879	0,817	-	1,503	0,142	1,823	1,909
	[3,844]	[2,866]	-	[66,15]	[7,550]	[94,23]	[69,29]
hardware	0,122	2,136	1,890	-	-0,359	1,320	1,964
	[0,452]	[5,184]	[6,526]	-	[-1,87]	[7,382]	[5,640]
comm.	0,548	0,424	1,464	1,241	-	1,562	1,835
	[5,109]	[2,208]	[11,28]	[14,29]	-	[18,40]	[11,20]
software	-0,440	2,954	2,423	0,680	-0,679	-	2,135
	[-0,92]	[4,232]	[4,271]	[2,172]	[-2,00]	-	[3,598]
non ict	1,104	1,126	1,440	1,480	0,122	1,801	-
	[33,67]	[43,31]	[25,88]	[40,01]	[3,103]	[40,94]	-

Boostrap estimations using 50 repetitions and samples of 250 observations

Figures in brackets are $t-$students statistics

Table A.3: Morishima elasticities (ICT non intensive

	Factor i						
	Workers (education level)			Capital			
Factor j	high	medium	low	hardware	comm.	software	non ict
high	-	0,354	1,550	1,434	-0,253	1,724	2,101
	-	[0,906]	[4,201]	[51,74]	[-13,0]	[84,24]	[43,72]
medium	0,723	-	1,184	1,478	-0,260	1,722	2,063
	[1,873]	-	[2,831]	[52,43]	[-9,07]	[47,72]	[106,0]
low	1,179	0,658	-	1,505	-0,208	1,780	1,995
	[8,514]	[4,540]	-	[143,6]	[-24,3]	[195,4]	[136,6]
hardware	-0,073	0,711	3,445	-	-0,697	1,285	2,240
	[-0,10]	[1,067]	[4,817]	-	[-2,71]	[4,119]	[5,527]
comm.	0,381	-0,089	1,972	1,109	-	1,384	2,154
	[0,994]	[-0,14]	[3,631]	[5,871]	-	[5,713]	[6,899]
software	-0,092	-0,496	5,334	0,681	-1,034	-	2,517
	[-0,10]	[-0,32]	[4,216]	[1,617]	[-2,33]	-	[3,616]
non ict	1,321	0,878	1,663	1,491	-0,206	1,763	-
	[28,18]	[44,11]	[49,64]	[99,72]	[-12,8]	[141,7]	-

Boostrap estimations using 50 repetitions and samples of 250 observations

Figures in brackets are $t-$students statistics

B Testing the equality of elasticities across sectors

Table B.1: Testing equality of elasticities

t-**student for demand and cross elasticities differences**

	Factor i						
	Workers (education level)			Capital			
Factor j	high	medium	low	hardware	comm.	software	non ict
high	5.45	8.39	10.45	4.35	3.16	7.30	22.20
medium	8.16	2.75	5.16	23.27	10.43	31.63	14.49
low	1.72	5.35	1.46	15.78	35.33	8.56	17.06
hardware	6.76	12.63	12.41	1.52	0.71	0.90	2.67
comm.	6.56	4.85	6.73	4.63	1.88	7.90	5.20
software	0.30	18.55	20.24	2.01	0.10	0.30	2.77
non ict	9.58	5.18	43.51	5.65	11.70	5.63	8.74

t-**student for Allen-Uzawa elasticities differences**

	Factor i						
	Workers (education level)			Capital			
Factor j	high	medium	low	hardware	comm.	software	non ict
high	-	-	-	-	-	-	-
medium	7.20	-	-	-	-	-	-
low	6.32	5.74	-	-	-	-	-
hardware	10.24	11.20	5.33	-	-	-	-
comm.	7.43	5.61	1.07	11.15	-	-	-
software	4.72	17.32	12.00	8.29	13.42	-	-
non ict	19.66	15.88	14.39	1.42	5.33	2.08	-

Boostrap estimations using 100 repetitions and samples of 100 observations for ICT intensive sectors, and 250 observations for ICT non intensive sectors. t-students in absolute terms. Degrees of freedom are estimated using Welch's (1947) formula.

C Description of regressors

Temporary rate The temporary employment rate is defined as the ratio of the number of wage earners under a fixed-term contract relative to the total number of workers (i.e. those workers under fixed-term contracts plus those under tenured or permanent contracts). The series of the number of workers under both types of contract are available from the INE from 1987:2 to date, for four aggregate sectors (Agriculture, Industry, Construction and Services). Before the labor market reform of 1984, fixed term contracts were limited to some seasonal activities such as agriculture or services associated with tourism. We have looked back and extended (1980 to 1987) the series of temporary workers using the annual labor series in the EU KLEMS database. From the EU KLEMS database, we calculate the ratio of the number of low skilled workers in the primary and in the hotel and restaurant services sectors relative to the total number of workers. The fraction is used as a proxy for the temporary rate for the years 1977 to 1986, since the series from INE lacks this information. For the two years 1985 and 1986, we interpolate the values using our estimate for 1984 and the INE rate for 1987. On average, the temporary rate was 10.37% between 1976 and 1984, which is near those estimated by some other authors.

Figure C.1 presents the temporary employment rate, defined as the proportion of wage earners with a temporary contract. The evolution of the temporary rate documents an essential feature of the Spanish labor market: a dual system of labor contracts. Before 1984, the use of temporary contracts was limited to some seasonal activities such as agriculture and tourism. Throughout the 1990s and before the great recession, the temporary rate always exceeded 30%.

Collective bargaining Figure C.2 presents a collective bargaining centralization index estimated by Ochel (2000), which ranges within the [1,3] interval. For Spain, the index presents values between 2 and 3, meaning that collective bargaining takes place at the sector level (value 2) or at the upper central level (value 3). Flanagan (1999) discusses how macroeconomic performance can be related to the collective bargaining system: an increase in wage bargaining decentralization allows firms to adapt to changing circumstances. Then, the theory predicts that centralization may help moderate wage formation. According to Ochel's (2000) indices, Figure C.2 reflects that a change in the Spanish collective bargaining system took place in the mid-1980s, on par with an increase in openness (coming from the 1986 EEC membership) and the 1984 labor market reform. Throughout the same period, there was a downturn in the level of collective bargaining coordination, affecting factors such as common contract expiration dates and federation, or government influence on wage setting.

Employment protection Figure C.3 presents the employment protection indices proposed by Allard (2005), constructed upon that of the OECD, which considers a variety of permanent and temporary worker protections and collective dismissals.[6] Allard (2005) extended the OECD methodology for a longer horizon (1950 to 2003) and takes into account other aspects of protection that constrain firms' hiring and firing decisions, such as the scope of bargaining in substituting official legal protection and the role of private litigation.

Allard's index reports an increase in protection during the 1970s, a peak in 1983 followed by a decline after the 1984 labor market reform; the reform mainly affected hiring decisions related to temporary contracts. Allard's index also captures the effects of the second labor market reform of 1994, which relaxed the terms of dismissal for permanent workers.[7] Although the standards of both reforms were aimed at introducing flexibility, in practical terms they have accounted for a duality problem in the Spanish labor contract: while severance pay for temporary workers is low and certain, it is high and subject to a huge risk of litigation for tenured workers. Firms have all the incentives to rely on temporary workers during booms and to dismiss them during the early months of recessions.

Other unmeasured factors The period under consideration, 1980-2005, includes a considerable number of institutional reforms in Spain's recent history. As an illustration, in Figure C.4 we report the overall index of world economic freedom for Spain proposed by Gwartney, Lawson, and Hall (2012) and some of its components therein: legal system and property rights, credit market regulation, and freedom to trade internationally. In the case of regulation, a higher index should be associated with fewer regulations in the credit market. Both the overall index and the three sub-items evince an increase in economic freedom up to 2000, when apparently many of the reforms came to a halt in Europe. In an attempt to measure the benefits from openness and globalization, our regression analysis includes the sub-index "freedom to trade internationally".

[6] For instance, with respect to permanent employment, there are three items under consideration: contract legislation, notice periods for individual dismissals and severance pay, and penalties for unfair dismissals.

[7] The 1994 reform also allowed for more flexibility inside the firms (the workweek, the functional and the geographical mobility) and reformed some other labor market institutions (e.g. collective bargaining and the INEM, *Instituto Nacional de Empleo*).

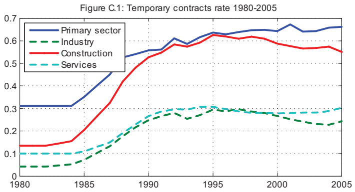


Figure C.1: Temporary contracts rate 1980-2005

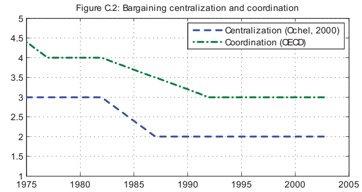


Figure C.2: Bargaining centralization and coordination

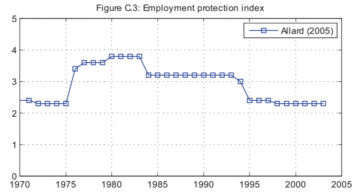


Figure C.3: Employment protection index

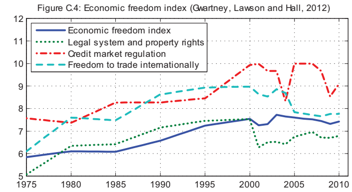
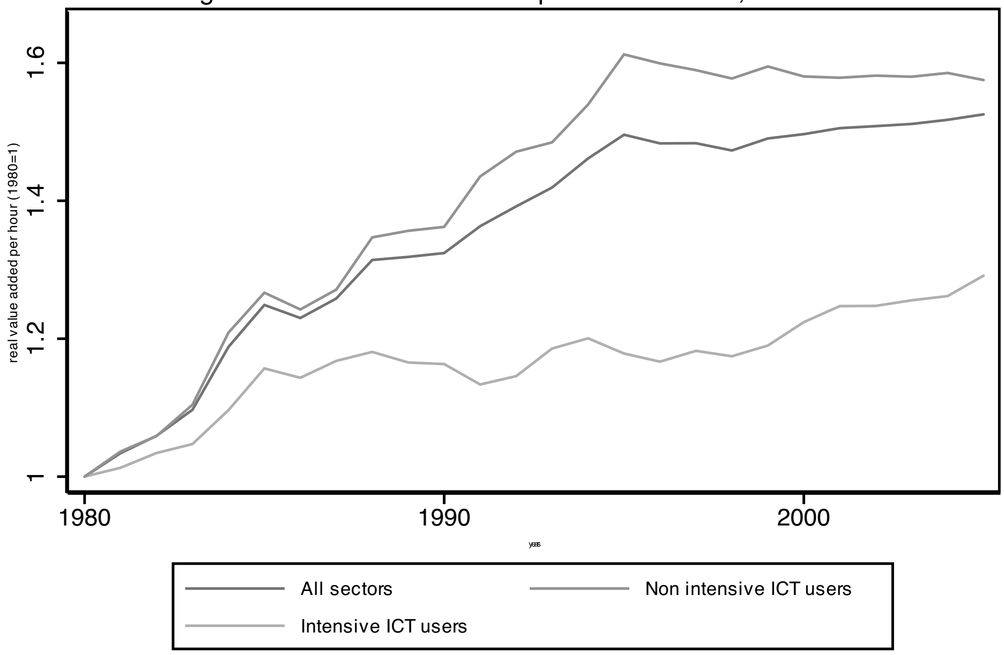


Figure C.4: Economic freedom index (Gwartney, Lawson and Hall, 2012)

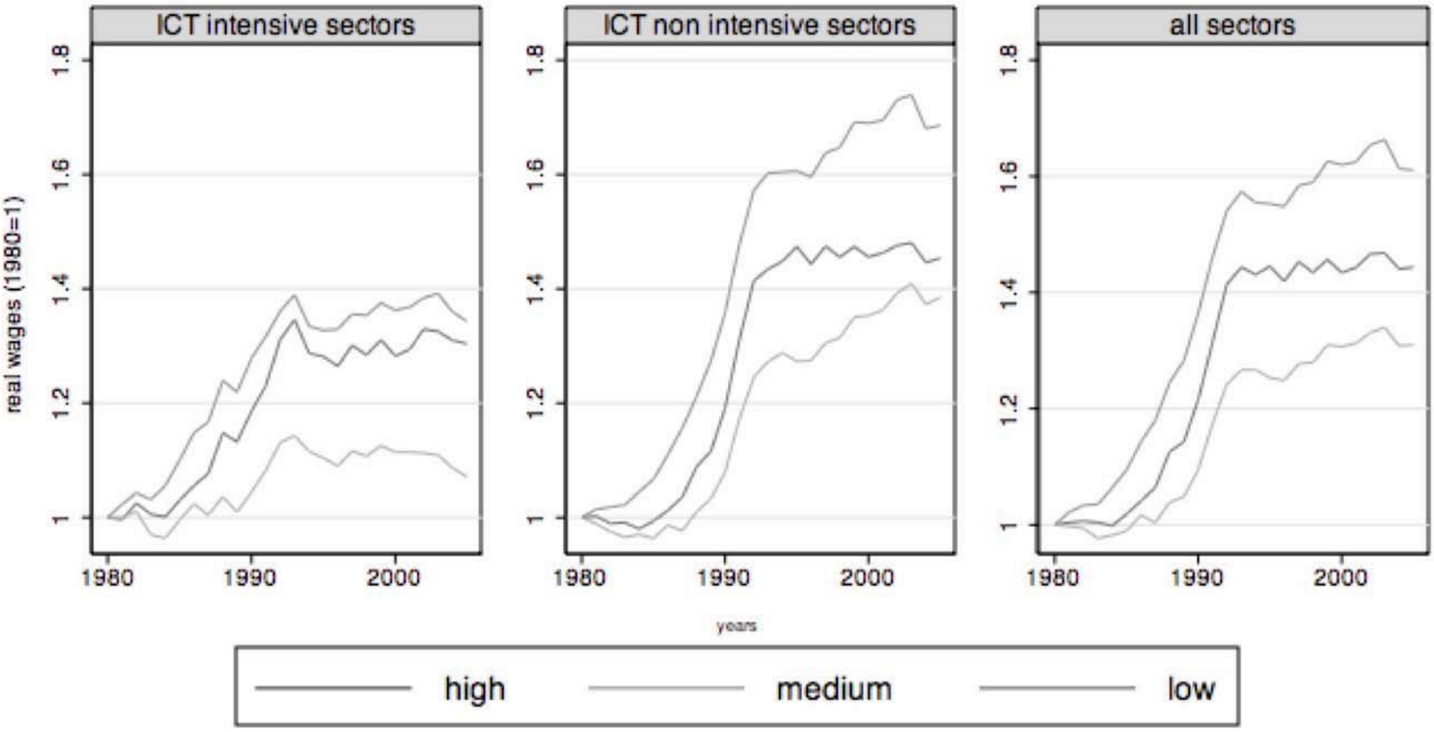
Figure 1. Gross value added per hour worked, 1980-2005



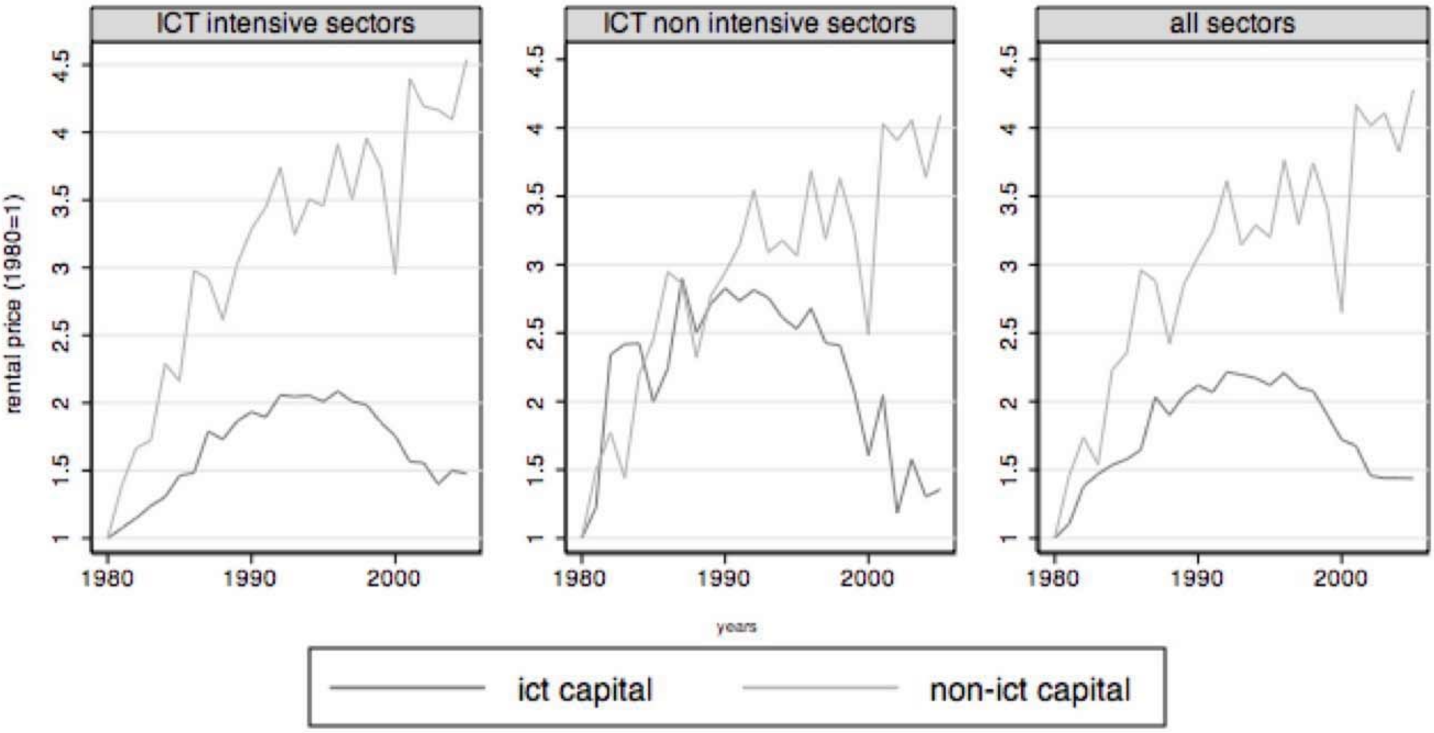
Source: EUKLEMS, Ivie-FBBVA and own estimations

Figure 2: Price indexes, 1980-2005

A. Real wage index by level of education



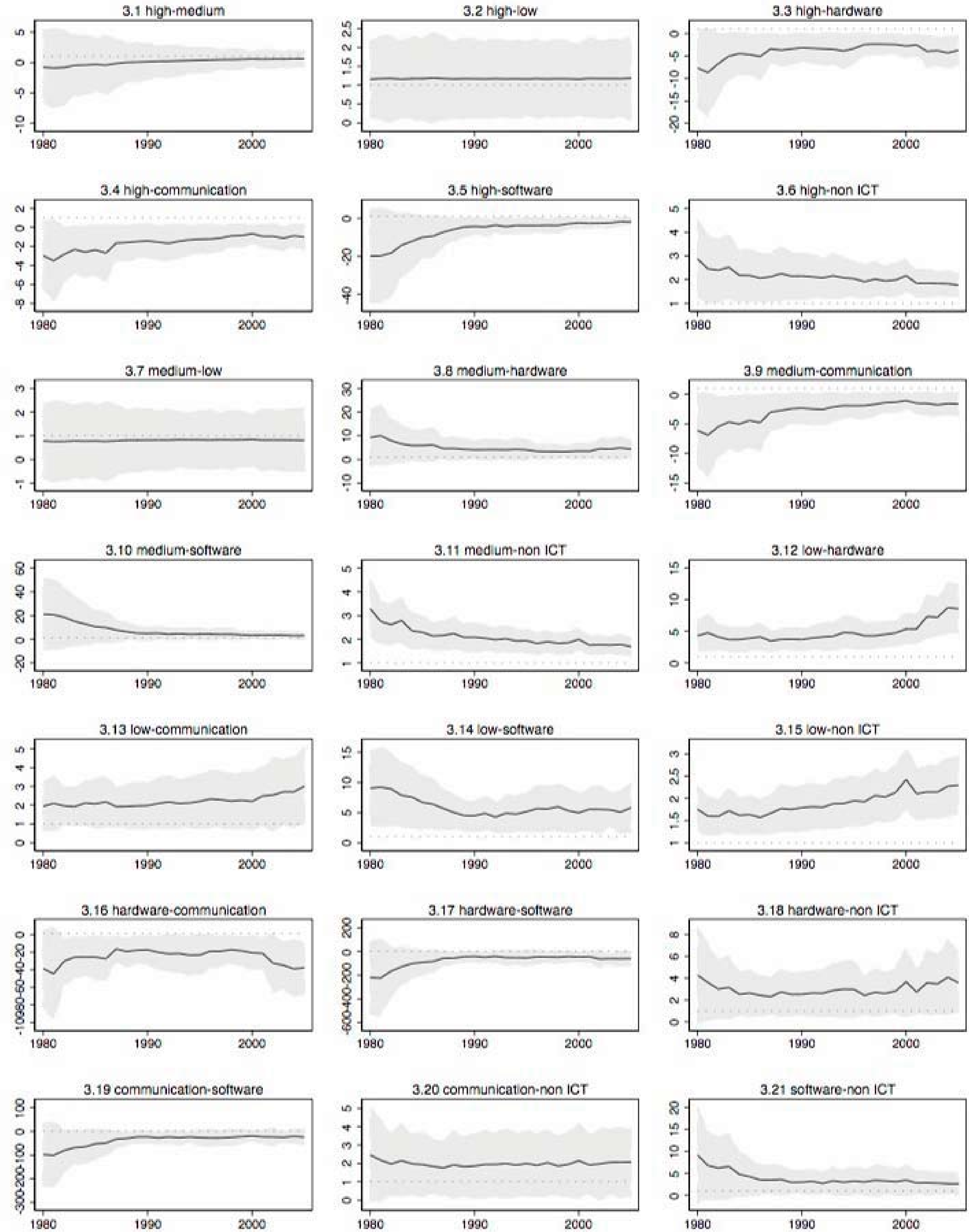
B. Rental price index by type of capital



Source: EUKLEMS, Ivie-FBBVA and own estimations

Figure 3. Elasticities of substitution, 1980-2005

(all sectors)



Note: Shadowed areas represent 95% confidence intervals. Dotted lines are fixed to one